APPENDIX D
DEVELOPMENT OF A WATER QUALITY PLAN FOR THE COLUMBIA RIVER MAINSTEM: A FEDERAL AGENCY PROPOSAL

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D.1 EXECUTIVE SUMMARY

Fish runs in the Columbia River basin have declined due to a number of factors, including habitat loss across the basin, hatchery production, fish harvest, and hydropower development (Federal Caucus, 1999). As a result, 12 stocks of fish in the Columbia River basin that are directly and/or indirectly impacted by the Federal Columbia River Power System (FCRPS) are now listed as threatened or endangered under the Endangered Species Act (ESA). There are also current exceedances of Clean Water Act (CWA) water quality standards (total dissolved gas [TDG] and temperature) that impact fish health and overall beneficial uses in the Columbia and Snake river mainstem.

The effect of water quality on Federally listed anadromous fish in the basin requires that both issues be addressed in a coordinated manner. Therefore, the Environmental Protection Agency (EPA), the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (USFWS), and the Federal Action Agencies [U.S. Army Corps of Engineers (Corps); Bureau of Reclamation (BOR); and Bonneville Power Administration (BPA)] are undertaking efforts to conserve listed species under the ESA and create a nexus of water quality improvements consistent with the CWA.

The ESA and the CWA are compatible and complementary statutes offering opportunities to conserve listed species and improve overall system water quality. Both laws stress the importance of maintaining ecosystem integrity. Recognizing that system improvements for fish and wildlife can benefit water quality, EPA, NMFS, USFWS, and the Action Agencies intend to integrate their fish and wildlife and water quality efforts in the form of actions to support the objectives and responsibilities of the ESA, CWA, and other fish and wildlife and water quality statutes such as the Northwest Electric Power Planning and Conservation Act.

This appendix describes current activities and planning for improvements in fish survival that can also serve to improve water quality by reducing TDG and temperature. It also describes efforts that EPA, NMFS, USFWS, and the Federal Action Agencies have decided to undertake now and those they believe can benefit the survival and recovery of listed species. Pertinent portions of this appendix are included in the 2000 NMFS Biological Opinion under Sections 9.6.1.7, Water Quality, and 9.6.5, Research, Monitoring, and Evaluation, as part of the discussion of a reasonable and prudent alternative.

Over the longer term, with a focus on water quality, EPA, NMFS, USFWS, and the Federal Action Agencies — the Corps, BPA, and BOR — commit to participate in development and implementation of a water quality plan that supports TDG and temperature water quality improvements to the Columbia River basin, mainly in the portions of the Columbia, Snake, and Clearwater rivers where Federal dams exist. The water quality plan is anticipated to be consistent with the Columbia/Snake River mainstem total maximum daily load (TMDL) limits that are currently being developed by EPA, the states, and the Tribes. Water quality plan implementation anticipates that EPA, NMFS, and the Federal Action Agencies will properly integrate implementation of the water quality plan to ongoing TMDL development activities on the mainstem and in the subbasins.

Water quality planning will complement ESA recovery planning efforts by including a development and implementation process consistent with existing planning and review processes, such as the NMFS Regional Forum, scientific peer review, and in some cases, congressional approval.

To successfully implement the water quality plan for the FCRPS, a coalition of Federal, state, Tribal, and other appropriate representatives is necessary to integrate the efforts of all interested stakeholders and provide a connection with existing broad-scale coordination efforts that are ongoing in the basin. The water quality plan should include implementation measures to improve water quality. These measures, like ESA and fish and wildlife measures, will be coordinated with established processes. These include planning and review processes of the Northwest Power Planning Council, including the Independent Scientific Review Panel, the Columbia Basin Fish and Wildlife Authority, the NMFS Regional Forum, and, if appropriate, the Columbia Basin Forum. Some measures may also require congressional approval. NMFS, EPA, USFWS, and the Federal Action Agencies intend to support implementation of measures that successfully garner approval through these processes. A common approach for selecting water quality, ESA, and fish and wildlife measures to implement will foster coordination among NMFS, EPA, and the Federal Action Agencies, and increase effective use of limited available resources. The outcome of this coordinated approach will be a collection of measures the Action Agencies undertake to serve the agencies various statutory purposes within budgetary parameters. Recommendations approved via applicable processes could be identified in the water quality plan for implementation.

D.2 WATER QUALITY PLAN

D.2.1 Background

Under the CWA, EPA is encouraging states and Tribes to develop water quality plans for the Columbia River basin. EPA will lead development of the portion of these plans that address the Columbia River waters from Lake Roosevelt on the Columbia River, Dworshak Dam on the Clearwater River, and the Brownlee Dam on the Snake River to the tailrace of Bonneville Dam. The EPA, NMFS, USFWS, and the Federal Action Agencies value consistency of their actions with water quality plans, as well as other plans developed in the Pacific Northwest region. As the Action Agencies make recommendations and decisions, they will take existing water quality plans into account.

The proposed RPA water quality plan describes TMDLs consistent with state and Tribal water quality standards and identifies ways that activities affecting water quality can reduce adverse effects on water quality. The EPA, NMFS, USFWS, and the Federal Action Agencies intend to participate in this development in order to discern further how they can reduce or offset TDG levels and temperature increases associated with their activities.

D.2.2 Columbia/Snake River Mainstem System Water Quality Plan

The following outlines how a water quality plan could be developed and implemented. Federal agency representatives developed a water quality plan process to establish a decision process for both operational and structural water quality measures . This process was created to enable decision-making on the biological, cost-effective and, economic implications of water quality measures. Details regarding the process, development, and implementation of a water quality plan may vary, depending on coordination with states and Tribes and interested persons in the Pacific Northwest.

D.2.3 Project Scope

The water quality plan should consist of a systemwide analysis of the factors that affect temperatures and dissolved gas levels. The analysis will result in development of a suite of recommended actions to improve water quality, using established water quality standards as both the goal and measure of progress for the basin. The Columbia River tributaries and mainstem will be treated as an ecosystem, with the mainstem addressed alongside tributary efforts.

The water quality plan will focus primarily on the physical and operational changes to both Federal and non-Federal dams that may benefit water quality in terms of temperature and dissolved gas while improving the survival rates of ESA-listed species. Other factors that affect water quality, such as grazing, agriculture, forest practices, point sources, land use, mining, and water withdrawals, are being addressed in other forums, including the states' TMDL processes. Discharges to the mainstem that impact gas and temperature and are not covered in tributary TMDLs may be addressed in this plan.

For the initial phase, the plan will address actions from the international boundary on the Columbia River, Dworshak Dam on the Clearwater River, and Brownlee Dam on the Snake River to the tailrace of Bonneville Dam. Future work may include considerations above the international boundary. While the plan will aim to take into account the role of tributaries in mainstem water quality problems, it will not seek specific remedies in the tributaries. Ongoing CWA TMDL processes and other water quality improvement initiatives are under way in many of the tributaries and should not be delayed in anticipation of the plan.

Mechanisms to implement the water quality plan include the 2000 Biological Opinion for the FCRPS and other agreements as appropriate. For non-Federal dams, CWA, the Federal Energy Regulatory Commission (FERC), and appropriate state and Tribal authorities will be involved in implementation.

It is not the primary goal of the water quality plan to target revision of beneficial uses or standards. The purpose is to identify and test hypotheses, implement reasonable actions to improve water quality, and to consider potential revisions to beneficial uses or standards, based on broader societal, legal, and policy considerations (40 CFR 131.10(g)) as appropriate. The goals of the water quality plan is are as follows:

- To assist in our understanding of systemwide loading capacity and loading allocation by assessing the existing effects at Federal and non-Federal dams and tributaries.

- To provide an organized, coordinated approach to improving water quality, with the goal of meeting water quality standards that the states can integrate into their water quality management programs.

- To provide a framework for identifying, evaluating, and implementing reasonable actions for dam operators to use as they work toward reducing temperature and dissolved gas levels.

- To provide a record of the actions that are and are not feasible for structural and operational improvements aimed at improving water quality conditions and meeting water quality standards. This information may provide a basis for future beneficial use and water quality criteria revisions.

- To bring basin-wide information into the decision processes regarding dissolved gas and temperature, and to provide technical assessment of a project's relative value in terms of water quality.

- To integrate dissolved gas and temperature work into one process for both Federal and non-Federal dams on the mainstem Columbia/Snake system.

D.2.4 Plan Process

Implementation of the water quality plan could be accomplished as an additional responsibility of existing teams (and/or other basin forums) or, as may be more effective, through creation of a water quality improvement team as discussed in Section 5 of this report. The water quality improvement team would link and attempt to integrate actions by the NMFS Regional Forum and the Columbia River Basin Forum, through input and updates on water quality plan implementation. In implementing the water quality plan, the water quality improvement team would also link the traditional TMDL development and implementation processes to this new effort to improve water quality on the mainstem Columbia River (see Table D-1). The team would have specific TDG and temperature sub-committees.

Table D-1. Decision-making Process to Implement the Water Quality Plan

Water Quality Plan Development Process	Relationship to TMDL Planning Process	Who leads?	Who Assists (seek advice/kept informed)?	Item Completion Date
Model development and calibration	Identify applicable water quality criteria/goals	EPA, state agencies		To Be Determined (TBD)
Alt. Development	identify source of loadings, including natural background	WQDIT, state agencies	WQT/IT, Forum	TBD
Modeling, Alt. Development, and Screening	allocate pollutant loadings	WQDIT, state agencies	WQT/IT, Forum	TBD
Alt. Screening, Alt. Analysis	final development of a water quality implementation plan	Federal execs, state execs, Tribes/IT, Forum	Federal execs, state execs, Tribes/IT, Forum	TBD
Decisions/Actions	implement the plan			TBD
Decisions/Actions	monitoring and evaluate plan effectiveness	WQDIT/IT, Forum	WQDIT/IT, Forum	TBD

D.2.5 Participants

The water quality improvement team would be composed of senior policy analysts and key technical staff from Federal agencies (EPA, NMFS, USFWS, Corps, BPA, and BOR), states (Oregon, Washington, and Idaho), Columbia River Tribal governments, and non-Federal entities such as public utility districts, municipalities, and Idaho Power Company.

D.2.6 Schedule

The first iteration of the water quality plan (including a detailed workplan and timeline) should be completed by the fourth quarter of FY 2000, or as soon thereafter as practical.

D.3 TOTAL DISSOLVED GAS

D.3.1 Dissolved Gas Goal

The long-term dissolved gas goal is to reach the dissolved gas (TDG) standard, which is currently 110%, in all critical habitat in the Columbia and Snake River basins while taking actions to recover listed species in the basin. For anadromous fish, achieving the goal would mean fish passage survival levels consistent with the performance standards for the mainstem projects.

This goal is intended to guide operating and capital improvement decisions relating to TDG created during periods of spill. A systemwide approach is needed to address gas generated at mainstem projects where fish are present, and at upstream facilities (i.e., outside the current range of listed salmon) in both the U.S. and Canada, the five Public Utility District dams on the Columbia River between the Snake River and Chief Joseph Dam, and the Hells Canyon complex on the Snake River. There are some exceptions noted in the ability to meet the state and Tribal TDG standard.

Without physical modifications to the dams beyond those that are presently under way, the long-term TDG goal cannot be attained in the near term between April and August at and between the eight mainstem FCRPS dams. This is a result of the need to rely on spill to safely pass juvenile salmon around those dams. A similar issue exists with Dworshak Dam, where in some circumstances spill is necessary to contribute to the attainment of spring and summer flow objectives for salmon migration and water temperature standards in the Clearwater and lower Snake rivers. Therefore in the near term, it will be necessary to conduct spill operations that cause exceedances of the 110% TDG gas standard. The Corps is responsible for ensuring that the spill program, and the Snake River flood control shift from Dworshak, are conducted in a manner consistent with applicable state and Tribal water quality standards, including compliance with any related procedural requirements, such as obtaining any necessary exemptions, special conditions, waivers, modifications, site specific criteria, or standards changes. In any event, the spill operations shall comply with the special TDG conditions set forth below.

To ensure progress toward the long-term goal, the Corps, BOR, and BPA will also work with NMFS, USFWS, EPA, the Columbia River Tribes, and the states of Washington, Oregon, Idaho, and Montana. This work will take place through an adaptive management process as a part of the water quality plan to accomplish the following:

- Make operational and capital investment decisions at the Federal projects to reduce levels of gas generated by spill and to reduce the reliance on spill as a primary means of juvenile fish passage.

- Fund, implement, and report on adequate physical and biological TDG monitoring to assess compliance with state and Tribal water quality standards and other special conditions that may apply.

- Fund and implement modeling to better assess and act on TDG water quality issues.

The feasibility of meeting the long-term goal will be revisited annually during the water quality improvement planning process.

D.3.2 Special TDG Conditions for Juvenile Fish Passage

At the eight Columbia/Snake River mainstem projects, spill will be reduced as necessary when the average TDG concentration of the 12 highest hourly measurements per calendar day exceeds 115% of saturation at the forebay monitor of any Snake or lower Columbia river dam or at the Camas/Washougal station below Bonneville Dam. Spill will also be reduced when the 12-hour average TDG levels exceed 120% of saturation at the tailrace monitor at any Snake or lower Columbia River dams or Dworshak Dam. Spill will also be reduced when instantaneous TDG levels exceed 125% of saturation for any two hours during the 12 highest hourly measurements per calendar day at any Snake, Clearwater, or lower Columbia River monitor.

> [**Note seeking comment**: Since 1995, NMFS has annually applied to Washington, Oregon, Idaho, and the Nez Perce Tribe for waivers from the 110% standard to allow for juvenile fish passage and flow augmentation spill as described above. All have granted waivers (or temporary standard changes) consistent with the interim exception at some times and under certain circumstances. NMFS appreciates this support in meeting the survival requirements of listed salmon. NMFS also appreciates the continued willingness to work with NMFS and the other Federal agencies. However, operation of FCRPS projects consistent with water quality standards is the responsibility of the Action Agencies, not NMFS. State water quality agencies and the EPA have repeatedly and consistently made the point that annual waivers are not an appropriate means of addressing these issues.
>
> Through the opportunity to review and comment on this Biological Opinion, NMFS and the Action Agencies are seeking recommendations from the states and Tribes on how to go about the approval processes described above.]

D.4 UPDATE ON SPILL AND 1995 RISK MANAGEMENT

D.4.1 Background

In 1995, the fish agencies and the lower Columbia Tribes released a paper called Spill and 1995 Risk Management, which presented the benefits of spill for juvenile fish passage, the risks associated with spill-generated gas, and the survival rates of juveniles passing through other routes.

Since 1995, a small number of dissolved gas research projects has continued. Extensive physical and biological monitoring has been implemented to track the effects of the spill program. The intent of the risk assessment update is to review the research results, and to review the results of 5 years of monitoring. The update should provide a basis for evaluating the options being considered in the 2000 Biological Opinion.

D.4.2 Summary

Gas bubble disease research efforts have been reduced, reflecting the opinion of decision-makers that sufficient biological knowledge exists to manage the spill program. The main thrusts of research have addressed gas bubble signs and depth compensation for supersaturated conditions.

Work on gas bubble disease has characterized its signs, incidence, severity, progression, and relevance. It has been shown that gas bubble signs correlate to exposure, are progressive, and may be useful in understanding their biological implications. Interpretation of signs must be pursued cautiously, however, due to variations in persistence, inconsistencies involving exposure length and water depth, and extreme variability in gas bubble signs.

Depth compensation research has not been extensive, and the results are incomplete and preliminary. However, it does appear that juveniles may get some protection from migration at depths ranging from approximately 1.5 to 2.5 meters. Results from adult studies indicate these fish may be negotiating the Columbia and Snake river migration corridors at depth compensatory to a surface dissolved gas of 130%. If one accepts these results as representative, it could mean that the Biological Opinion targets of 115 to 120% dissolved gas pose little problem to migrants.

Five years of physical dissolved gas and biological monitoring have accompanied implementation of the spill program. Juvenile and adult salmonids, resident fish species, and aquatic insects have been monitored for the incidence and severity of gas bubble disease.

Results of physical monitoring have recorded dissolved gas supersaturation levels in forebays and tailraces of each FCRPS project, as well as the impacts of voluntary and involuntary spill. The physical monitoring program has provided a spill and dissolved gas management tool for compliance with state water quality standards waivers.

The results of the biological monitoring program have also proven to record accurately the effects of the spill program. The overall number of fish affected with signs over the years has proven to be less than originally assumed when the 1995 Biological Opinion was developed. The average incidence of signs increases above 1% when dissolved gas exceeds 115%. When fish with signs are exposed to gas levels greater than 120%, there is an increasing trend in incidence and severity. The most severe signs display a similar trend above 125%. Two of the 5 years, 1996 and 1997, were characterized by high volumes of involuntary spill, with gas levels ranging from 130 to 140% for days. In these two years the incidence of signs of gas bubble disease was 3.2 to 3.3% of the fish observed. In 1995, 1998, and 1999, the number of fish affected with signs ranged from 0.04 to 0.7% as a result of the 1995 and 1998 Biological Opinion spill program. During these years, the TDG levels were maintained at 115 to 120% in the forebay and tailrace, respectively.

D.5 TEMPERATURE

D.5.1 Water Temperature Goal

The long term goal for water temperature is standard attainment in all critical habitat in the Columbia and Snake river basins.

D.5.2 Water Quality Standards for Columbia River Temperatures

D.5.2.1 Washington Standards:WAC173-201A-130

Washington has a class-based system for determining appropriate levels of protection. The Columbia River is designated Class A from the mouth to the Grand Coulee Dam. It is designated Class AA (the highest class) from the Grand Coulee Dam to the Canadian border.

The Columbia River from the mouth to the Washington-Oregon border (river mile 309.3) is Class A. Special conditions are that temperature shall not exceed 20° C due to human activities. When natural conditions exceed 20° C no temperature increases will be allowed that raise the receiving water temperature by greater than 0.3° C due to any single source or 1.1° C due to all such activities combined.

The Columbia River from the Washington-Oregon border (river mile 309) to Grand Coulee Dam (rivermile 596.6) is Class A. Special conditions from the Washington-Oregon border (river mile 309) to Priest Rapids Dam (river mile 397) are that temperatures shall not exceed 20° C due to human activities. When natural conditions exceed 20° C, no temperature increases will be allowed that raise the receiving water temperature by greater than 0.3° C. Nor shall such temperature increases at any time exceed t=34(T+9). There is a special fish passage exemption as described in WAC173-201A-060(4)(b).

The Columbia River from Grand Coulee Dam (river mile 596.6) to the Canadian border (river mile 745) is Class AA. Temperature criteria for Class AA waters are that temperatures shall not exceed 16° C due to human activities. When natural conditions exceed 16° C no temperature increases will be allowed that raise the receiving water temperature by greater than 0.3° C.

D.5.2.2 Oregon Standards: ORS 340-041- Basin (b)(A)(ii)

Oregon has a use-based system for designating waters for protection. The Columbia River has been designated for salmonid rearing from the mouth to the Deschutes River basin. The stretches in the John Day and Umatilla basins are designated for salmonid rearing and spawning. However, the Columbia River has its own temperature criteria. Therefore, the spawning and rearing criteria do not apply to the Columbia River, even though it may be designated for rearing and/or spawning. The Snake River is designated for salmonid spawning and rearing, and the respective criteria do apply.

No measurable surface water temperature increase resulting from humanly based activities is allowed in the Columbia River or its associated sloughs and channels from the mouth to river mile 309 when the surface water temperature exceed 68° F (20° C). For those basins that contain portions of the Snake River (Grande Ronde, Powder, Malheur, Owyhee), the temperature criteria are 64° F for rearing times, 55° F for spawning times.

D.5.2.3 Idaho Standards

There are two use designations that apply to the Snake River, cold water biota and salmonid spawning. Cold water biota standards are 22° C (71.6° F) instantaneously and 19° C (66.2° F) maximum daily average. Salmonid spawning standards are 13° C (55.4° F) instantaneously and 9° C (48.2° F) maximum daily average.

D.5.2.4 Colville Tribe Standards

The use designations and corresponding temperature criteria are as follows:

Class I (Extraordinary) - Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting: Temperature shall not exceed 16° C due to human activities. Temperature increases shall not, at any time, exceed $t=23/(T+5)$. When natural conditions exceed 16° C, no temperature increase will be allowed which will raise the receiving water by greater than 0.3° C. For purposes hereof, "t" represents the permissive temperature change across the dilution zone; and "T" represents the highest existing temperature in this water classification outside of any dilution zone. Provided that temperature increase resulting from nonpoint source activities shall not exceed 2.8° C and the maximum water temperature shall not exceed 10.3° C.

Class II (Excellent) - Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting: Temperature shall not exceed 18° C due to human activities. Temperature increases shall not, at any time, exceed $t=28/(T+7)$. For purposes hereof, "t" represents the permissive temperature change across the dilution zone; and "T" represents the highest existing temperature in this water classification outside of any dilution zone. Provided that temperature increase resulting from nonpoint source activities shall not exceed 2.8° C and the maximum water temperature shall not exceed 18.3° C.

Class III (Good) - Fish and shellfish: Salmonid migration, rearing, spawning, and harvesting: Temperature shall not exceed 21° C due to human activities. T increases shall not,at any time, exceed $t=34/(T+9)$. For purposes hereof, "t" represents the permissive temperature change across the dilution zone; and "T" represents the highest existing temperature in this water classification outside of any dilution zone.Provided that temperature increase resulting from nonpoint source activities shall not exceed 2.8° C and the maximum water temperature shall not exceed 21.3° C.

Class IV (Fair) - Salmonid migration. Temperature shall not exceed 22° C due to human activities; T increases shall not exceed $t=20/(t+2)$.

In the mainstem Columbia/Snake River, attainment of the temperature standard is very complex, due to a number of interrelated factors that affect water temperatures at certain times of the year and to the limited ability to alter water temperature in the mainstem. In the tributaries, attainment of the temperature standard is also complex, due to many of these same factors and the long time needed to realize the temperature benefits of remedial actions (such as riparian restoration). Therefore, in the near term, working with the state and/or Tribe with relevant regulatory authority, the interim goal is to take actions to move toward attaining the standard. Actions to be taken where TMDLs are not yet in place will be consistent with the annual collaborative process described in the following paragraph. Once TMDLs are in place, actions will be consistent with these TMDLs for each relevant water quality limited body.

To ensure progress toward the long-term goal, the Corps, BOR, and BPA will also work with NMFS, USFWS, EPA, the Columbia River Tribes, and the states of Washington, Oregon, Idaho, and Montana through an adaptive management process as a part of the water quality plan to achieve the following:

- Make operational and capital investment decisions at the FCRPS projects to move toward attainment of thermal water quality standards.
- Seek consensus on offsite mitigation measures that would contribute to attainment of water temperature standards.
- Fund, implement, and report on adequate physical and biological temperature monitoring to assess compliance with state and Tribal water quality standards and other special conditions that may apply.
- Cooperate with others to fund implementation and modeling to better assess and act on thermal water quality problems and opportunities.
- Develop emergency measures that may be needed to address immediate and acute water temperature problems affecting listed salmon.

The feasibility of meeting the long-term goal will be revisited annually during the water quality improvement planning process.

D.5.3 Reservoir Operations

Reservoir existence and operation can have strong effects on water temperatures in the reservoir and in downstream reaches. Water temperature conditions have a complex array of effects on salmonids. Intergravel water temperatures affect the rate of embryonic development, with about 50° F degree-days needed for emergence (Weatherley and Gill 1995). Post-emergence growth rates are directly related to water temperature. Water temperatures experienced by outmigrating juvenile salmon have been shown to affect survival (Connor, et al. 1998, Smith 1998, Muir, et al. 1999). Water temperature also indirectly affects salmon survival. Foraging rates of piscivorous fish are directly related to temperature (Vigg and Burley 1991), and the rates of infertility and mortality of several diseases are known to be directly related to temperature (NMFS 1998).

The presence of hydroelectric dams has modified natural temperature regimes in the mainstream Columbia River. Snake River basin reservoirs are known to affect water temperatures in the river (Yearsley 1999) by extending water residence times and by altering the heat exchange characteristics of affected river reaches. Seasonal temperature fluctuations generally decrease below larger reservoirs that are thermally stratified and have hypolimnetic discharges. Downstream temperatures are cooler in the summer as cold hypolimnetic waters are discharged, but warmer in the fall as energy stored in the epilimnion during the summer is released (Spence 1996). Thermal storage provided by the Snake River reservoirs reduces seasonal variations in stream temperatures in much the same way as seasonal variations in streamflow. There is a documented upward trend in spring water temperature that is consistent with the introduction of storage in upstream reservoirs (NRC 1996). Thus, operation of storage reservoirs affects both the thermal characteristics of the river and the thermally regulated aspects of salmon survival. For this reason, the thermal effects of reservoir operation are an important consideration in developing system operations aimed at protecting and restoring listed salmonids.

An emerging issue is potential water temperature effects on juvenile outmigration timing (NMFS 2000). The hypothesis is that Snake River juvenile fall chinook outmigration timing is delayed by cooler-than-historical water temperatures during incubation and early rearing life stages. This effect may be exacerbated by delayed spawning due to excessively warm fall temperatures. Because Snake River water temperatures and juvenile salmon mortality rates increase from mid-July through mid-September, delaying out-migration timing reduces juvenile fall chinook survival. Migrating adults can be delayed by excessively warm water temperatures (Karr et al. 1998). In addition, fall chinook spawning is inhibited by temperatures above 61° F (McCullough). Delay can reduce the ability of adult fish to survive to spawning and their vigor and fecundity during spawning.

D.5.4 Summer Operations at Dworshak, Brownlee, and McNary Dams

The EPA, NMFS, USFWS, and the Federal Action Agencies intend to abate or offset temperature impacts associated with FCRPS operations. To assess the feasibility of reducing temperatures in ways beneficial to fish, EPA, NMFS, USFWS, and the Federal Action Agencies intend to engage in the following modifications to the summer operations of a number of mainstem dams.

D.5.4.1 Dworshak Dam

During the summer and early fall, cool water releases from Dworshak Dam can offset water temperature problems in the lower Snake and lower Columbia rivers. Given the tremendous significance of these cool water releases on the Columbia/Snake mainstem and the severe limitations of substantive measures to alleviate high water temperatures in the Columbia and Snake River mainstem, decisions regarding Dworshak releases may be the most critical in the near-term attempt to moderate water temperature problems for migrating juvenile and adult salmon in the lower Snake River. Therefore, the Federal Action Agencies must commit to a scientifically sound approach to ensure the best use of these Dworshak releases into the Columbia/Snake mainstem. These decisions will need to be made in the context of existing forums and in concert with the Nez Perce Tribe and the State of Idaho.

D.5.4.2 Brownlee Dam

Cool water releases at Brownlee Dam may provide relief for water temperature problems in the lower Snake River. Commitment on these releases will be developed through the ongoing forum process and through the FERC relicensing process.

D.5.4.3 McNary Dam

Because of the configuration of the Snake and Columbia rivers and the location of McNary Dam, high water temperatures in the juvenile fish facilities have provoked fish kills over the years. For the 2000 migration season or as soon as possible, emergency measures shall be put in place for McNary Dam when water temperatures reach certain thresholds. These emergency measures will serve to help fish move through the fish passage system or prevent holding of fish awaiting transport.

D.5.5 Long-Term Temperature Modeling

In order to assess the system’s ability to respond to proposed structural and system operational changes to temperature, three primary options exist as follows:

- The EPA Region 10 one-dimensional model
- The COLTEMP model of the Corps Reservoir Control Center
- The proposed two-dimensional water temperature model

It is the intention of the Federal Action Agencies that this modeling work be coordinated. The Federal Action Agencies shall clearly identify needs and uses of each of these models.

D.5.5.1 EPA Region 10 One-Dimensional Model

The EPA one-dimensional model characterizes the relative contribution of reservoirs and tributary flows to changes in water temperatures of the Snake and Columbia rivers. The model shows it is likely that both the duration and magnitude of water temperatures exceeding the benchmark (20° C) in the Columbia and Snake River mainstem is greater with the dams in place than it would be with the dams removed. The likelihood of these events remains essentially unchanged when existing conditions are changed in the model such that tributary temperatures are equal to or less than 16° C. The model simulations indicate that the impact of hydroelectric projects on water temperatures in the mainstem Columbia and Snake rivers is greater than that of the major tributaries. The initial conditions for the Snake River at Lewiston, Idaho, are such that the average timespan when water temperatures exceed the benchmark is approximately 11% and the average magnitude of the exceedance is approximately 1° C. This model is available for use in the near term.

D.5.5.2 COLTEMP Model

The COLTEMP numerical model is a one-dimensional water temperature model that provides conceptual information about water temperature conditions in Columbia River reservoirs. COLTEMP is not an operational model for regulatory real-time reservoir use. Rather, it is a water management tool used to evaluate how reservoir regulation changes could impact the water temperature structure of reservoirs. The potential changes in the water temperature structure of the reservoirs are taken into consideration during water-release scheduling. The COLTEMP model outputs, however, are not forecasted water temperature predictions.

COLTEMP is a simplified version of the Corps' HEC5-Q water quality model. The model uses the concept of mass balance to move water downstream. The fundamental transport mechanisms are advection (the horizontal movement of a mass of water) and diffusion (movement from a region of higher concentration to a region of lower concentration). External sources determining water temperature include point sources and water withdrawals. Point sources include headwater flow, tributary stream flow, and water withdrawals. The major non-point source is solar radiation. Point sources are represented by daily flow rates multiplied by the corresponding water temperatures. Withdrawals remove mass at the rate of the outflow multiplied by the computed ambient water temperature. As a one-dimensional model, COLTEMP does not consider any degree of thermal stratification within the reservoir. Accuracy of the water temperature output depends on the accuracy of water temperature, weather, and river flow data. The model showed that it adequately represented the one-dimensional thermal dynamics of reservoirs during summer seasons in the Columbia reservoirs in the 1994 interagency study called the Columbia River System Operation Review.

D.5.5.3 Future Two-Dimensional Model

Because reservoir stratification can have effects on salmon survival that cannot be well defined by single-depth monitoring data and one-dimensional models, the Action Agencies, with NMFS and EPA participation, should also develop a two-dimensional model of Columbia/lower Snake mainstem water temperature characteristics. To be useful, this model should be capable of estimating bulk average temperatures and providing estimated temperatures on a relatively small two-dimensional scale. This model should also connect the biological aspects of fish presence and specific temperature tolerances to the specific locations of water temperatures in order to yield a better understanding of water temperature impacts and possible solutions. This model should be fully integrated with the one-dimensional input model described above.

The distribution of flow (velocities) is another important component to understanding and modeling reservoir temperature characteristics. A density current could develop along the bottom of the reservoir, conveying the coldest water through the reservoir with little effect on near-surface water temperature conditions.

D.6 STRUCTURAL, OPERATIONAL, AND PROCEDURAL MEASURES TO ADDRESS TDG AND TEMPERATURE ISSUES WITHIN THE FCRPS

D.6.1 Structural and Operational Measures: The A-List and B-List

The water quality plan, while having a CWA-oriented focus on beneficial uses and water quality standards, will interface with ESA compliance by integrating implementation of its A-List (Table D-2) and B-List (Table D-3). The A-List consists of ongoing, funded structural and operational studies that address TDG and temperature impacts from the FCRPS. Implementation of the A-List actions, although more related to ESA compliance than CWA compliance, should result in an improved ability of the FCRPS to support the type of water quality improvements that will meet designated beneficial uses. B-List items consist of long-term studies and potential projects at FCRPS dams that support implementation of the CWA and complement actions supporting anadromous fish recovery.

Integrating the studies and actions of the two lists allows the water quality plan to support water quality improvement in the mainstem and complement other related actions and measures that support anadromous fish recovery. The EPA, NMFS, USFWS, and the Federal Action Agencies intend to take reasonable steps to abate TDG and to offset temperature impacts associated with FCRPS operations. To assess the feasibility of reducing temperatures in ways beneficial to fish, EPA, NMFS, USFWS, and the Federal Action Agencies intend to modify summer operations of a number of mainstem dams. EPA, NMFS, USFWS, and the Federal Action Agencies will select for implementation measures that serve the ESA, CWA, and other environmental statutes in a coordinated manner.

D.6.2 Procedural Measures: Decision Process to Implement the Water Quality Plan

There are a number of existing basin forums that address various aspects of salmonid protection and recovery. For example, the NMFS Regional Implementation Forum is principally an ESA-focused intergovernmental forum for regional discussion and decisions on operation and system configuration of the FCRPS. The Columbia River Basin Forum is an entity created by a Memorandum of Agreement among Federal, State, and some Tribal governments that have management responsibilities and treaty rights regarding Columbia River Basin fish and wildlife. Although the Columbia River Basin Forum does not have any decision-making authority, it does provide the opportunity for the participants to focus on the most pressing issues in order to improve effectiveness of regional fish and wildlife recovery efforts. There are also ongoing interactions between the EPA, states, municipalities, industry, and Tribes on tributary TMDL development.

Table D-2. "A-List" - Ongoing Dissolved Gas and Temperature Activities

Activity Type	Activity/Description	FY OO Estimate ($000s)	FY 01 Estimate (000s)	Balance to complete (000s)	Implementation cost TBD
	LOWER GRANITE				
S	Gas fast track - Initiate activities in FY 00. Modify general and sectional models, as required, and begin testing. Conduct near-field performance tests. Provide preliminary implementation cost estimate.	$80	$675	$12,790	
	LITTLE GOOSE				
S	Gas fast track - Complete sectional model tests and general model construction in FY 00. Develop alternatives, complete evaluations, and prepare final report in FY 01. Provide preliminary implementation cost estimate.	$400	$1,600	$14,562	
	LOWER MONUMENTAL				
S	Gas fast track - Initiate construction and testing of general model in FY 00. Complete model construction and testing in FY 01. Complete sectional model tests and general model construction in FY 00. Develop alternatives, complete evaluations, and prepare final report in FY 01. Provide preliminary implementation cost estimate.	$1,250	$665	$7,340	

Table D-2 continued.

Activity Type	Activity/Description	FY OO Estimate ($000s)	FY 01 Estimate (000s)	Balance to complete (000s)	Implementation cost TBD
	ICE HARBOR				
I/S	Flow deflectors - Completed construction in FY 99. Conduct spill survival and fish passage efficiency studies in FY 00 and 01.	$720	$720	$0	
	McNARY				
S	Gas fast track - Complete physical model construction and initiate model testing and design in FY 00. Complete alternative evaluations and prepare final report in FY 01. Provide preliminary implementation cost estimate.	$1,885	$430	$7,065	
	JOHN DAY				
	Gas fast track - Initial 1-year, near-field evaluation to determine whether modification of new existing flip lips warrants further investigation.	$100	TBD	TBD	
	THE DALLES				
S	Gas fast track - Initiate study in FY 01. Modify existing physical models, complete model testing, and initiate design document. Provide final report in FY 02.		$430	$230	yes

Table D-2 continued.

Activity Type	Activity/Description	FY OO Estimate ($000s)	FY 01 Estimate (000s)	Balance to complete (000s)	Implementation cost TBD
	BONNEVILLE				
S	Gas fast track - Complete testing and evaluation of alternatives for additional deflectors and modifications to existing and draft final report in FY 00. Finalize report coordination in early FY 01.	$460	$510	$0	
I	Implement gas fast track - Placeholder to initiate design Plans Specifications for fast track measure based on FY 00 decision. Preliminary total cost estimate.		$150	$14,350	
	CHIEF JOSEPH				
S	Flow deflectors - Complete feasibility study and NEPA EIS in FY 00; construction is proposed for FY 02-03.	?	?	$40,000	
	GRAND COULEE				
S	Gas Abatement Feasibility Study - Complete feasibility study in FY 00.	$150	$200	$0	

Table D-2 continued.

Activity Type	Activity/Description	FY OO Estimate ($000s)	FY 01 Estimate (000s)	Balance to complete (000s)	Implementation cost TBD
	SYSTEM				
S	Gas abatement study - Complete systemwide analysis and draft final report and recommendations in FY 00. Incorporate comments and finalize report in FY 01. (Costs include both Portland and Walla Walla Corps Districts).	$950	$192	$0	yes
S	Temperature Model Development and Testing - Mainstem Columbia River and FDR reservoir.	?	?	?	
S	Transboundry Water Quality Team - Develop work plan and initiate planning for systemwide abatement.	?	?	?	
S	Gas fast track - Conduct physical injury study at Ice Harbor.	$0	$100	TBD	

Notes: TBD = to be determined
S = study
I = implementation
P&S = Engineering Plans and Specifications

Table D-3. "B-List" - Potential Dissolved Gas and Temperature Activities[1]

Facility	Proposal
Bonneville	Baffled Spillway - Study
Bonneville	Additional Deflectors and Mods.
John Day	Modify Flow Deflectors - Implementation
McNary	Side Channel Spillway - Study
Dworshak	Raised Stilling Basin - Study
Dworshak	Operational Changes for Temperature Downstream
Lower Granite	Side Channel Spillway or Raised Stilling Basin - Study
Lower Monumental	Side Channel Spillway or Raised Stilling Basin - Study
Little Goose	Side Channel Spillway or Raised Stilling Basin - Study
Ice Harbor	Side Channel Spillway or Raised Stilling Basin - Study
Libby	Flow Deflectors - Study
Chief Joseph	Flow Deflectors - Implementation
Grand Coulee	Outlet Works Modifications - Implementation
Lower Snake River Dams	Lower Snake Temperature Monitoring
Lower Snake River Dams	Lower Snake Radio-Telemetry Temperature Mortality Monitoring
3 Collector Dams and McNary	Temperature Monitoring in Bypass Facilities
Systemwide	Physiological/Disease Monitoring of Temperature Impacts to Adult and Juvenile Salmon
Lower Columbia Dams	Near Field Temperature Monitoring
Systemwide	Development/Refinement of Temperature Modeling (1 and 2 dimensional)

[1] Many of these activities are contingent on studies in **Table D-2**. All projects are subject to approval

The final organizational design to discuss, develop, and implement the water quality plan should be based on the following objectives:

- Ensure that all appropriate participants are at the table or have access to the necessary meetings where water quality plan implementation is discussed.
- Make the most expeditious use of all participants' time.
- Organize participants well to get the job done.
- Avoid redundancy in existing organizational structures.

D.6.3 The Water Quality Improvement Team

None of the ongoing forums and/or ongoing water quality protection activities may provide the desired organizational structure to fully integrate the goals and regulatory requirements of the CWA and ESA in a manner that supports development and implementation of the water quality plan for the mainstem Columbia and Snake rivers. It is also important for EPA, NMFS, USFWS, and the Federal Action Agencies to understand the relationship between the Water Quality Plan and ongoing TMDL planning processes, particularly their relationship with each other and evaluation and implementation of the system improvements and studies. Therefore, final development and implementation of the plan could be accomplished through creation of a water quality improvement team (WQIT) of senior policy analysts and supported by technical staff from Federal agencies (EPA, NMFS, USFWS, Corps, BPA, and BOR); the states of Oregon, Washington, and Idaho; Columbia River Tribal governments; and non-Federal entities such as municipalities and PUDs.

The team would also have specific TDG and temperature technical subcommittees to be included under the overall umbrella of team actions. The water quality improvement team is considered to be a cross-connecting link between the NMFS Regional Implementation Forum and the Columbia River Basin Forum, through input and updates on water quality plan implementation. By the fourth quarter of fiscal year 2000, the water quality improvement team would develop a detailed workplan and timeline to identify key TDG and temperature studies and implementation of structural and operational changes to the FCRPS system, including PUDs. The timeline would provide specific milestones to conclude discussions on technological issues related to structural and operational changes to the FCRPS, consultation with the other basin forums discussed above, and implementation of actions leading to the 2006 mid-point evaluation under the RPA.

In developing the water quality plan, the water quality improvement team would incorporate the traditional TMDL development and implementation process with this new effort to improve water quality standards on the mainstem Columbia River (see Table D-1). In order to accomplish this goal, the water quality improvement team would seek advice from the NMFS Regional Implementation Forum when necessary. The water quality improvement team would make funding recommendations for federal projects through the system configuration team of the

NMFS Regional Implementation Forum, but would also seek other funding for capital structural improvements through traditional agency-focused funding mechanisms. Recommendations by the water quality improvement team or existing group would undergo the same prioritization and budgeting processes as other actions undertaken or supported by the Action Agencies (see Section 1 of this report).

The water quality improvement team, while having a CWA focus on beneficial uses and on developing and implementing the water quality plan, would interface with ESA compliance by integrating implementation of the A-List and B-List (see Table D-2) as appropriate to support water quality improvement in the mainstem, and to complement other related actions and measures that support anadromous fish recovery as well as water quality improvement in the tributaries. As part of the water quality improvement team, EPA, NMFS, USFWS, and the Federal Action Agencies would review the A and B lists annually and revise them as needed, after taking into consideration the best available scientific information.

D.6.4 Project Selection Criteria

The possible actions identified on the A and B lists are at the heart of implementing the water quality plan. Therefore, it is important that both lists contain the all appropriate studies and structural and operational changes necessary to comply with and complement the goals of the ESA and the CWA. In order to appear on the A or B Lists, proposals should go through a well-defined screening, prioritization, funding, allocation, and approval process.

The following criteria are proposed for use by the water quality improvement team to screen A and B List items. The water quality improvement team can then provide advice and recommendations to the system configuration team of the NMFS Regional Implementation Forum as they prioritize projects as part of the Corps' Columbia River Fish and Mitigation Program.

Proposed criteria for evaluating possible actions are as follows:

- How does the proposal meet the tenets of the 2000 Biological Opinion for the FCRPS and the water quality plan (i.e., how does the proposal complement the two activities)?
- How does the proposal demonstrate substantial progress toward meeting the 110% TDG and temperature standards by the 2004 check-in point?
- If the proposal is a study, how will it increase the existing knowledge base to meet the temperature and/or dissolved gas standard?
- How does the proposal build on existing science to achieve project goals?
- How does the proposal go beyond mitigation for FCRPS impacts to enhance anadromous fish recovery?

- Is the proposal cost-effective?
- Is there consensus among Federal, State, and Tribal representatives to implement the proposal?

D.6.5 Integration of Water Quality Plan with Other Processes

The water quality plan will include possible measures for implementation to improve water quality. These measures, like ESA and fish and wildlife measures, will be coordinated with established processes. These include planning and review processes of the Northwest Power Planning Council, including the Independent Scientific Review Panel, the Columbia Basin Fish and Wildlife Authority, the NMFS' Regional Forum, and, if appropriate, the Columbia River Basin Forum. Some measures may also require congressional approval.

NMFS, EPA, USFWS, and the Federal Action Agencies intend to support implementation of those measures that successfully garner approval through these processes. A common approach for selecting water quality, ESA, and fish and wildlife measures to implement should foster coordination among NMFS, EPA, USFWS, and the Federal Action Agencies, and increase effective use of available but finite resources. The outcome of these processes is a collection of measures undertaken by the Action Agencies to serve the agencies' various statutory purposes within budgetary parameters. Recommendations approved by applicable processes could be identified in the water quality plan for implementation.

D.7 MONITORING AND EVALUATION

As part of implementing the water quality plan, the Federal Action Agencies need to install, maintain and operate a complete water quality monitoring network. That network should include a water temperature and dissolved gas data collection protocol. At a minimum such a protocol should include descriptions of instrument precision and accuracy, measures to ensure quality control, consistent and reliable recording of time and date; and, for data collected in reservoirs, depth. The protocol should also consider data formatting requirements and should be available for downloading from a website. Such information is useful in evaluating the temperature and dissolved gas-related effects of specific operational strategies and may be useful in devising operations that better protect anadromous fish. At this time, there is a comprehensive dissolved gas monitoring network in the Columbia/Snake mainstem. However, there are perceived data gaps in a comprehensive temperature monitoring program.

Various entities have collected available water temperature data throughout the basin for an array of purposes (Yearsley 1999). Quality assurance/quality control programs ensure that some of these data are collected with sufficient precision, accuracy, and frequency to serve a variety of purposes. For other data, this is not the case. Much of the data collected are from relatively imprecise instruments and may be subject to errors in accuracy. For example, turbine scroll case water temperatures may be collected sporadically, using instruments capable of reading to the nearest 1 $^{\circ}$ F. These dial-type thermometers are subject to parallax errors and inaccurate reading by observers.

Furthermore, few researchers perceived the need to correlate temperature conditions with current and historical reservoir operations information. Due to reservoir thermal stratification and the physical layout of hydroelectric projects, temperatures in downstream reaches can be affected by reservoir operations. Water temperatures downstream from stratified reservoirs could vary at a given point in time depending on the relative contribution of spill (which comes from warmer near-surface water) to total discharge. If viewed alone, temperature data from such operational effects could appear to be errors in a one-dimensional model.

Thus it is important to know current and historical upstream project operations, as well as the distribution of water temperatures in the upstream reservoir when estimating the likely downstream water temperature effects of a given operation.

Several FCRPS reservoirs are known to stratify during the summer. Specifically, Lake Roosevelt (Grand Coulee) on the Columbia River and Lower Granite and Little Goose reservoirs on the lower Snake River stratify (Karr and Mundy 1998). Due to severe gassing problems at Grand Coulee Dam, the very large turbine discharge capacity of the project, and the fact that salmon have been extirpated from habitat upstream from the project, the project is routinely operated to minimize spill. Stratification at Lake Roosevelt has very limited potential to adversely affect listed salmon.

In contrast to the situation at Lake Roosevelt, Lower Granite and Little Goose reservoirs lie within currently occupied salmon habitat and frequently exhibit temperature conditions that could adversely affect salmon survival. Near-surface temperatures are frequently as much as 6° F warmer than temperatures near the bottom of the reservoir. Understanding the thermal characteristics of these reservoirs is important to our efforts to devise long-term management schemes to enhance salmon survival.

In order to adequately address temperature monitoring at mainstem reservoirs, the Federal Action Agencies should develop and maintain a model or series of models capable of estimating water temperatures of the Snake River, from Hells Canyon Dam on the Snake and from Dworshak Dam on the North Fork of the Clearwater River, to the confluence of the Snake River with the Columbia River downstream from Ice Harbor Dam. The models should be developed to function both as planning tools and to provide predicted outcomes in real-time. Both one-dimensional and multiple-dimensional models would be needed to fully define the temperature conditions within the reach (see the previous modeling discussion in Section D.5 of this appendix).

Until a modeling technique is selected, defining a data collection scheme is somewhat risky. That is, better data could possibly be developed at lower cost if the data needed to effectively drive the model were perfectly understood. Statistical tests may be available to identify the data needs. However, it is clear that both additional water temperature and meteorological data are needed. It is strongly suggested that the EPA, NMFS, USFWS, and the Federal Action Agencies coordinate this effort with EPA and state water quality agencies.

As the Snake and Clearwater rivers are rapid, turbulent rivers, it is reasonable to assume that the free-flowing portion of the rivers are relatively isothermic at any given point and time. Existing tri-level thermograph data (Karr et al. 1998) from the Clearwater River inlet also support this assumption. Thus, a single well-placed temperature probe at each selected station in the free-flowing portions of the study streams would accurately define the water temperature at that point.

The number of additional meteorological stations needed to achieve the desired model accuracy is unknown. Given that the geographic scale of weather variations can be quite small, particularly during the summer (for example, summer convective storms), it is unlikely that all errors associated with extrapolation of site-specific conditions could be eliminated with any reasonable number of new stations. Again, a statistical analysis should be conducted to define the most important locations for new meteorological stations. All additional stations should discretely measure all of the meteorological variables necessary to construct a deterministic model of heat flux. Measured variables should include air temperature, relative humidity, barometric pressure, wind speed and velocity, solar radiation, and evaporation rates.

D.8 REFERENCES

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